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**Image Fusion Techniques: Final Report for Task Order 009
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Systems Engineering Solutions**

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Ball's WIRTO team would like to acknowledge the positive impact that this project's technical monitor, Dr. Dan Repperger, had upon all who were lucky enough to know him. Sadly, Dr. Repperger passed away during the course of this effort. Dr. Repperger is fondly remembered as being brilliant and tireless, with a dedicated work ethic and a willingness to mentor anyone in need. With an ability to give praise, encouragement, and credit to all his colleagues, he was an incredibly humble and gracious man who is greatly missed.

1.0 EXECUTIVE SUMMARY

This report describes the research and development (R&D) activity accomplished during the execution of Warfighter Interface Research and Technology Operations (WIRTO) Task Order 009. This effort focused upon the development of an Image Fusion Demonstration Program intended to illustrate the image quality associated with different techniques for blending and fusing multi-sensor imagery. The demo system consists of three components: (1) an OpenGL-based approach for blending multiple image types and combinations for a given image, (2) a viewer for comparing OpenGL-based blending and image fusion techniques for a given image set, and (3) a viewer that demonstrates image fusion results for multiple image sets.

2.0 SCOPE

2.1 Introduction

The primary work was developing an image fusion demonstration capability. The work took two different spectral bands of the same image and fused them together to develop a single enhanced image of the scene. This effort specifically led to the development of an Image Fusion Demonstration Program intended to illustrate the image quality associated with different techniques for blending and fusing multi-sensor imagery. The demo system consists of three components: (1) an OpenGL-based approach for blending multiple image types and combinations for a given image, (2) a viewer for comparing OpenGL-based blending and image fusion techniques for a given image set, and (3) a viewer that demonstrates image fusion results for multiple image sets.

2.2 Document Overview

This document outlines the technical and program management activities and accomplishments performed in developing an Image Fusion Demonstration Program that showcases image fusion techniques under study and development by AFRL's Human Effectiveness Directorate, Warfighter Interface Division, Battlespace Visualization Branch (AFRL/RHCV).

3.0 SPECIFIC PROJECT ACCOMPLISHMENTS

Technical support for the Image Fusion Demonstration effort involved the development of several software programs that demonstrate the fusing of multiple raw images into a single blended or fused image. These programs, built using OpenGL blending capabilities and AFRL/RHCV-developed image fusion capabilities, included an Image Blending Viewer demo, an Image Fusion and OpenGL Blending Comparison demo, and an Image Fusion demo. Technical activities performed in support of each of these are discussed below. This is followed by a brief outline of program management activities performed in support of the task.

3.1 Image Blending Viewer Demo

The first of the demos to be developed was the Image Blending Viewer demo. To begin, a C++ Class was filled out with various OpenGL functions pertaining to blending. Properties supported by the class include GL Blending Function, Depth Testing method, Lighting method (Light0 and Light1 are currently supported), Material Coloring method, and Texture Generation mode. All property functions developed allow for setting the method or function and the optional immediate enabling or disabling of the function or method. Once the property is defined, other OpenGL API functions can be used to enable or disable the various methods. A new constructor was defined so that an external texture mapping holder and texture count can be passed to the class by reference. This can support any number of textures to be used by the application without the need for providing space within the class that may otherwise be wasted; existing constructors still support up to three texture maps.

Making extensive use of the OpenGL wrapper class that was developed, Ball engineers developed the Image Blending Viewer. As depicted in Figure 1, the demo displays up to three registered images and merges them using an OpenGL blending function. This figure shows a long-wavelength infrared (LWIR) image, a medium-wavelength infrared (MWIR) image, and an image intensifier tube (IIT) image of a single scene. These raw images are at the periphery of the display. The center image in the figure shows the result of blending the LWIR and MWIR images using the OpenGL blending procedures. The image types to be blended can be selected via keyboard command; however, a timed automatic mode of the program serves as a standalone demonstrator.



Figure 1. Screenshot from Image Blending Viewer Demo

The images being blended are shown to move from their respective positions toward the center until they are perfectly superimposed. After a short delay, the next permutation of the fusion is effected with two (or all three) of the other images; the program will continuously cycle through all of the combinations. Text displayed under each image indicates each image type, and the blended image is labeled with text that indicates the fusion mode being demonstrated. The text is displayed using the textured font rendering functions previously developed for the in-house C++ OpenGL support library.

3.2 Image Fusion and OpenGL Blending Comparison Demo

The second demonstration program developed under this effort consisted of a comparison of OpenGL blending with a fusing process developed by AFRL/RHCV. See Figure 2. The comparison demo displays side-by-side, a fused image and a blended image of the same two source images. As shown in Figure 2, the program displays the two raw images in the top corners of the display. The blended and fused images created from the raw images are shown in the center of the display. The demo program works with a given image set name that is hard coded, but it can be made to work with any number of LWIR and IIT images available on the lab network drive. Note that the greater range of grayscale values in the fused image results in higher image contrast. Relative to the blending process, the fusion process also retains more sharpness and detail in the image. This illustrates an advantage of AFRL/RHCV's fusion process over the blending process.



Figure 2 Screenshot from Image Fusion and OpenGL Blending Comparison Demo

3.3 Image Fusion Demo

The final program, shown in Figure 3, was the Image Fusion Demonstration. Components of earlier demos were re-worked to show the fused images instead of the OpenGL blended approximations. In scroll mode, the individual images are brought together using OpenGL blending. When they are perfectly superimposed, the program displays the two images fused in place of the blended image. The program shows only LWIR and IIT fused images. It operates in a sequential or random viewer mode within a selected image set. Image sets can be selected by use of the Page Up/Down keys. Three different image sets are currently available for use with this program. The LWIR, IIT, and fused versions of each image in the selected image sets were converted to bitmap (.bmp) format using MATLAB script developed for this effort. The file structure of the BMP images was consolidated and simplified to make future porting of the programs easier.



Figure 3. Screenshot from Image Fusion Demo

3.4 The End Product

All three demonstration programs described above were populated with help menu displays that list the available key commands and their function. The help menus are displayed when the programs have been idle for a period of time, and they can also be accessed by pressing a function key. This facilitates use of the demonstration programs in an open self-guided tour environment. Observers are aided in how to use the programs and are encouraged to explore and investigate the technology on display. Status messages were added to confirm the user's requested command in-process or an undefined key strike. The programs share a similar look and employ a like user interface design.

As the project came to an end, executable files for the three demonstration programs described above were generated on a CD. A working file structure was included, allowing the programs to be run directly from the CD. Alternately, the file structure can be copied to a host PC hard drive for execution. It contains all image bitmap files, font files used by the programs, and the parameter file for setting program parameters. Project development files and source files for all programs and support libraries and classes were also included on the CD.

The demo programs were briefed to the Government Technical Monitor (TM) and interested colleagues. The programs were accepted by and delivered to the TM at the conclusion of the technical effort.

3.5 Program Management

In support of this effort, Ball's program management team performed a number of functions to ensure that the technical effort was performed and managed within the funding scope and schedule. The Program Manager (Mr. Rich Doerr) and supporting management, financial, and administrative personnel developed a number of task-specific Contract Data Requirements List (CDRL) items. These included data a Monthly Funds and Man-Hour Expenditure Report, a Quarterly Contract Funds Status Report, and a Monthly Project Status Report. Additional deliverable-related activities included the review and delivery of any Presentation Material, and development, review and delivery of the project Final Report.

In addition to deliverable development, the Program Manager performed a number of functions to coordinate the technical activities over the course of the effort. These included holding periodic meetings with the TM, the Contracting Officer's Technical Representative (COTR), the Ball technical team, and the subcontractors. Program management activities also included task planning, resource management, and subcontractor management activities to ensure that AFRL was receiving the support required throughout the life of the program.

4.0 CONCLUSIONS

In summary, this effort led to the successful development of demonstrations that illustrate the visual effects of combining multi-sensor, same scene imagery into a single fused or blended image. To the extent that a fused or blended image contains more essential information than any of the individual image inputs upon which it is built, it can facilitate a user's understanding of the state of the world that is captured in the imagery. These demos illustrate the visual effects associated with blending and fusing techniques, the performance impacts of which can be assessed in future empirical studies.

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

This acronym list contains both general acronyms and program-specific acronyms.

Acronym	Definition
AFRL	Air Force Research Laboratory
CDRL	Contract Data Requirements List
COTR	Contracting Officer's Technical Representative
DTIC	Defense Technical Information Center
IIT	Image Intensifier Tube
LWIR	Long Wavelength Infrared
MWIR	Medium Wavelength Infrared
R&D	Research and Development
RHCV	Human Effectiveness Directorate, Warfighter Interface Division, Battlespace Visualization Branch
SOW	Statement of Work
TM	Technical Monitor
TO	Task Order
WIRTO	Warfighter Interface Research and Technology Operations